CLAIMS

I/WE CLAIM:

1. A spectral analysis module, including a wavemeter, for a high repetition rate gas discharge laser having a laser output beam comprising a pulsed output of greater than or equal to 15 mJ per pulse, sub-nanometer bandwidth tuning range pulses having a femptometer bandwidth precision and tens of femptometers bandwidth accuracy range, for measuring bandwidth on a pulse to pulse basis at pulse repetition rates of 4000Hz and above, comprising:

a primary beam-splitter in the path of the laser output laser of the gas discharge laser operative to pass the vast majority of the output beam and to reflect a first small portion of the output beam, the primary beam splitter oriented at an angle to sufficiently reduce the fluence on the primary beam-splitter, and creating overlapping fresnel reflections in the first small portion of the laser output beam;

a secondary beam splitter made from a material having a damage threshold sufficiently high to tolerate the fluence created by the overlapping portion of the fresnel reflections in the first small portion of the output laser beam, the secondary beam splitter reflecting the vast majority of the first small portion of the output laser beam and passing a second small portion of the output laser beam;

a telescoping optic in the path of the second small portion of the output beam operative to demagnify the second small portion of the output beam onto a first stage diffuser receiving the demagnified second small portion of the output laser beam, the demagnification selected to keep the fluence in the overlapping fresnel reflections in the second small portion of the output laser beam below the damage threshold of the first stage diffuser.

2. The apparatus of claim 1 further comprising:

the telescoping optic comprising a cylindrical telescoping optic oriented to demagnify a long axis of the second small portion of the output laser beam more than a short axis of the second small portion of the output laser beam, redistributing the fluence of the second small portion of the laser output beam across the first stage

diffuser to keep any portion of the first stage diffuser from exceeding the damage threshold for the material from which the first stage diffuser is made.

3. The apparatus of claim 1 further comprising:

the vast majority of the first small portion of the laser output beam being reflected into a power detection module.

4. The apparatus of claim 2 further comprising:

the vast majority of the first small portion of the laser output beam being reflected into a power detection module.

5. The apparatus of claim 1 further comprising:

a focusing lens in the path of the second small portion of the laser output beam focusing the second small portion of the laser beam onto a second stage diffuser creating a focused second small portion of the laser output beam;

the second stage diffuser in the path of the focused second small portion of the laser output beam, the second stage diffuser creating a narrow cone of the focused second small portion of the laser output beam;

an optical interferometer in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam.

6. The apparatus of claim 2 further comprising:

a focusing lens in the path of the second small portion of the laser output beam focusing the second small portion of the laser beam onto a second stage diffuser creating a focused second small portion of the laser output beam;

the second stage diffuser in the path of the focused second small portion of the laser output beam, the second stage diffuser creating a narrow cone of the focused second small portion of the laser output beam;

an optical interferometer in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam.

7. The apparatus of claim 3 further comprising:

a focusing lens in the path of the second small portion of the laser output beam focusing the second small portion of the laser beam onto a second stage diffuser creating a focused second small portion of the laser output beam;

the second stage diffuser in the path of the focused second small portion of the laser output beam, the second stage diffuser creating a narrow cone of the focused second small portion of the laser output beam;

an optical interferometer in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam.

8. The apparatus of claim 4 further comprising:

a focusing lens in the path of the second small portion of the laser output beam focusing the second small portion of the laser beam onto a second stage diffuser creating a focused second small portion of the laser output beam;

the second stage diffuser in the path of the focused second small portion of the laser output beam, the second stage diffuser creating a narrow cone of the focused second small portion of the laser output beam;

an optical interferometer in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam.

9. The apparatus of claim 5 further comprising:

a slit in the path of the narrow cone of the focused small portion of the laser output beam selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the optical interferometer.

10. The apparatus of claim 6 further comprising:

a slit in the path of the narrow cone of the focused small portion of the laser output beam selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the optical interferometer..

11. The apparatus of claim 7 further comprising:

a slit in the path of the narrow cone of the focused small portion of the laser output beam selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the optical interferometer.

12. The apparatus of claim 8 further comprising:

a slit in the path of the narrow cone of the focused small portion of the laser output beam selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the optical interferometer.

13. The apparatus of claim 5 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

14. The apparatus of claim 6 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

15. The apparatus of claim 7 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

16. The apparatus of claim 8 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

17. The apparatus of claim 9 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

18. The apparatus of claim 10 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

19. The apparatus of claim 11 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the optical interferometer having a very narrow slit function and a very narrow free spectral range.

21. The apparatus of claim 5 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

22. The apparatus of claim 6 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

23. The apparatus of claim 7 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

24. The apparatus of claim 8 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

25. The apparatus of claim 9 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

26. The apparatus of claim 10 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

27. The apparatus of claim 11 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

28. The apparatus of claim12 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

29. The apparatus of claim 21 further comprising:

the mirror of the primary splitter is made of CaF_2.

30. The apparatus of claim 22 further comprising:

the mirror of the primary splitter is made of CaF_2.

31. The apparatus of claim 23 further comprising:

the mirror of the primary splitter is made of CaF_2.

32. The apparatus of claim 24 further comprising:

the mirror of the primary splitter is made of CaF_2.

33. The apparatus of claim 25 further comprising:

the mirror of the primary splitter is made of CaF_2.

34. The apparatus of claim 26 further comprising:

the mirror of the primary splitter is made of CaF_2.

35. The apparatus of claim 27 further comprising:

the mirror of the primary splitter is made of CaF_2.

36. The apparatus of claim 28 further comprising:

the mirror of the primary splitter is made of CaF_2.

37. The apparatus of claim 5 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

38. The apparatus of claim 6 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

39. The apparatus of claim 7 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

40. The apparatus of claim 8 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

41. The apparatus of claim 9 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

42. The apparatus of claim 10 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

43. The apparatus of claim 11 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

44. The apparatus of claim 12 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

45. The apparatus of claim 37, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

46. The apparatus of claim 38, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

47. The apparatus of claim 39, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

48. The apparatus of claim 40, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

49. The apparatus of claim 41, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

50. The apparatus of claim 42, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

51. The apparatus of claim 43, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

52. The apparatus of claim 44, further comprising:

an etched diffuser between the focusing lens and the micro slit providing a relatively narrow cone angle of diffusion into the micro slit.

53. A spectral analysis module, including a wavemeter, for a high repetition rate gas discharge laser having a laser output beam comprising a pulsed output of greater than or equal to 15 mJ per pulse, sub-nanometer bandwidth tuning range pulses having a femptometer bandwidth precision and tens of femptometers bandwidth accuracy range, for measuring bandwidth on a pulse to pulse basis at pulse repetition rates of 4000Hz and above, comprising:

a primary beam-splitting means in the path of the laser output beam of the gas discharge laser for passing the vast majority of the output beam and reflecting a first small portion of the output beam, the primary beam splitting means oriented at an angle to sufficiently reduce the fluence on the primary beam-splitting means, and creating overlapping fresnel reflections in the first small portion of the laser output beam;

a secondary beam splitting means made from a material having a damage threshold sufficiently high to tolerate the fluence created by the overlapping portion of the fresnel reflections in the first small portion of the output laser beam, the secondary beam splitting means reflecting the vast majority of the first small portion of the output laser beam and passing a second small portion of the output laser beam;

a beam narrowing means in the path of the second small portion of the output beam for demagnify the second small portion of the output beam onto a first stage diffusion means receiving the demagnified second small portion of the output laser beam, the demagnification selected to keep the fluence in the overlapping fresnel reflections in the second small portion of the output laser beam below the damage threshold of the first stage diffusion means.

54. The apparatus of claim 53 further comprising:

the beam narrowing means comprising a means for demagnifying a long axis of the second small portion of the output laser beam more than a short axis of the second small portion of the output laser beam, redistributing the fluence of the second small portion of the laser output beam across the first stage diffusion means

to keep any portion of the first stage diffusion means from exceeding the damage threshold for the material from which the first stage diffusion means is made.

55. The apparatus of claim 53 further comprising:

the vast majority of the first small portion of the laser output beam being reflected into a power detection means.

56. The apparatus of claim 54 further comprising:

the vast majority of the first small portion of the laser output beam being reflected into a power detection means.

57. The apparatus of claim 53 further comprising:

a focusing means in the path of the second small portion of the laser output beam for focusing the second small portion of the laser beam onto a second stage diffusion means creating a focused second small portion of the laser output beam;

the second stage diffusion means in the path of the focused second small portion of the laser output beam creating a narrow cone of the focused second small portion of the laser output beam;

a interferometer means in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam for creating an interference pattern.

58. The apparatus of claim 54 further comprising:

a focusing means in the path of the second small portion of the laser output beam for focusing the second small portion of the laser beam onto a second stage diffusion means creating a focused second small portion of the laser output beam;

the second stage diffusion means in the path of the focused second small portion of the laser output beam creating a narrow cone of the focused second small portion of the laser output beam;

a interferometer means in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam for creating an interference pattern.

59. The apparatus of claim 55 further comprising:

a focusing means in the path of the second small portion of the laser output beam for focusing the second small portion of the laser beam onto a second stage diffusion means creating a focused second small portion of the laser output beam;

the second stage diffusion means in the path of the focused second small portion of the laser output beam creating a narrow cone of the focused second small portion of the laser output beam;

a interferometer means in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam for creating an interference pattern.

60. The apparatus of claim 56 further comprising:

a focusing means in the path of the second small portion of the laser output beam for focusing the second small portion of the laser beam onto a second stage diffusion means creating a focused second small portion of the laser output beam;

the second stage diffusion means in the path of the focused second small portion of the laser output beam creating a narrow cone of the focused second small portion of the laser output beam;

a interferometer means in the path of the narrow cone of the focused second small portion of the second small portion of the laser output beam for creating an interference pattern.

61. The apparatus of claim 57 further comprising:

a selection means in the path of the narrow cone of the focused small portion of the laser output beam for selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the interferometer means.

62. The apparatus of claim 58 further comprising:

a selection means in the path of the narrow cone of the focused small portion of the laser output beam for selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the interferometer means.

63. The apparatus of claim 59 further comprising:

a selection means in the path of the narrow cone of the focused small portion of the laser output beam for selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the interferometer means.

64. The apparatus of claim 60 further comprising:

a selection means in the path of the narrow cone of the focused small portion of the laser output beam for selecting a relatively narrow slice of the narrow cone of the focused second small portion of the laser output beam for passage into the interferometer means.

65. The apparatus of claim 57 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

66. The apparatus of claim 58 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

67. The apparatus of claim 59 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

68. The apparatus of claim 60 further comprising:

the gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

69. The apparatus of claim 61 further comprising:

The gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

70. The apparatus of claim 62 further comprising:

The gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

71. The apparatus of claim 63 further comprising:

The gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the interferometer means having a very narrow slit function and a very narrow free spectral range.

72. The apparatus of claim 64 further comprising:

The gas discharge laser being an ArF gas discharge laser with a nominal laser output beam wavelength of 193.350 nm and the having a very narrow slit function and a very narrow free spectral range.

73. The apparatus of claim 57 further comprising:

the primary beam splitter means comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

74. The apparatus of claim 58 further comprising:

the primary beam splitter means comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

75. The apparatus of claim 59 further comprising:

the primary beam splitter means comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

76. The apparatus of claim 60 further comprising:

the primary beam splitter means comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

77. The apparatus of claim 61 further comprising:

the primary beam splitter means comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

78. The apparatus of claim 62 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

79. The apparatus of claim 63 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

80. The apparatus of claim 64 further comprising:

the primary beam splitter comprises a partially reflecting mirror at an angle of at least 70 degrees to the output laser beam for a beam having an output energy of at least 15 mJ.

81. The apparatus of claim 73 further comprising:

the mirror of the primary splitter means is made of CaF_2.

82. The apparatus of claim 74 further comprising:

the mirror of the primary splitter is made of CaF_2.

83. The apparatus of claim 75 further comprising:

the mirror of the primary splitter is made of CaF_2.

84. The apparatus of claim 76 further comprising:

the mirror of the primary splitter is made of CaF_2.

85. The apparatus of claim 77 further comprising:

the mirror of the primary splitter is made of CaF_2.

86. The apparatus of claim 78 further comprising:

the mirror of the primary splitter is made of CaF_2.

87. The apparatus of claim 79 further comprising:

the mirror of the primary splitter is made of CaF_2.

88. The apparatus of claim 80 further comprising:

the mirror of the primary splitter is made of CaF_2.

87. The apparatus of claim 57 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

88. The apparatus of claim 58 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

89. The apparatus of claim 59 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

90. The apparatus of claim 60 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

91. The apparatus of claim 61 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

92. The apparatus of claim 62 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

93. The apparatus of claim 63 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

94. The apparatus of claim 64 further comprising:

the size of the slit is selected to minimize fluence to the optical interferometer and at the same time to irradiate the full vertical extension of each of a plurality of photodiodes in a photodiode array contained within the wavemeter.

95. A method of measuring bandwidth for a high repetition rate gas discharge laser having an output laser bean comprising a pulsed output of greater than or equal to 15 mJ per pulse, sub-nanometer bandwidth tuning range pulses having a femptometer bandwidth precision and tens of femptometers bandwidth accuracy range, for measuring bandwidth on a pulse to pulse basis at pulse repetition rates of 4000Hz and above, comprising:

splitting the output laser beam of the gas discharge laser and passing the vast majority of the output beam and reflecting a first small portion of the output beam, the primary beam splitting occurring in an optic oriented at an angle to sufficiently reduce the fluence on the optic, and creating overlapping fresnel reflections in the first small portion of the laser output beam;

splitting the first small portion of the output laser beam in an optic made from a material having a damage threshold sufficiently high to tolerate the fluence created by the overlapping portion of the fresnel reflections in the first small portion of the output laser beam, the secondary splitting reflecting the vast majority of the first small portion of the output laser beam and passing a second small portion of the output laser beam ;

narrowing the second small portion of the output laser beam for demagnify the second small portion of the output laser beam and diffusing the narrowed second small portion of the output laser beam in a diffusion optic, the demagnification

selected to keep the fluence in the overlapping fresnel reflections in the narrowed second small portion of the output laser beam below the damage threshold of the diffusion optic.